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Aggregate Resources Inventory of the Hearst Area Cochrane District Northern Ontario

By Staff of the Engineering and Terrain Geology Section
Ontario Geological Survey

1984

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Every possible effort is made to ensure the accuracy of the information contained in this report, but the Ministry of Natural Resources does not assume any liability for errors that may occur. Source references are included in the report and users may wish to verify critical information.

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ABSTRACT

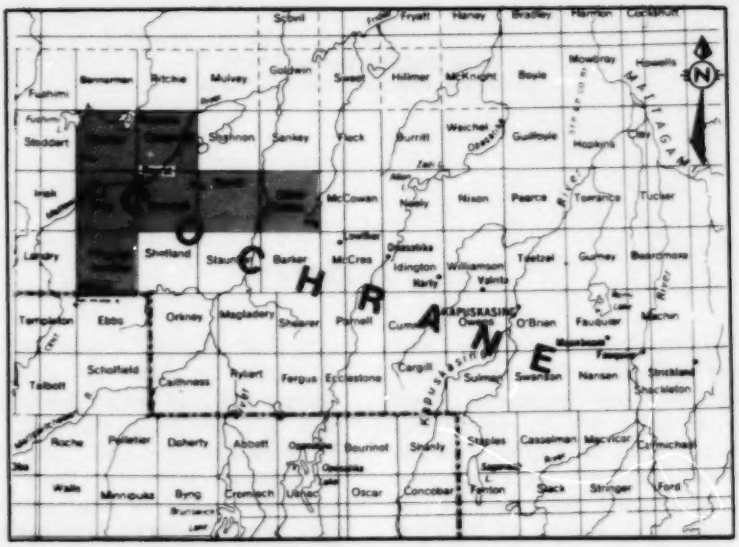

Figure 1 - Key Map Showing the Location of the Hearst Area, Scale 1:1 584 000.

This report includes both an inventory and evaluation of sand and gravel as well as the bedrock resources of seven townships in the Hearst Area. These townships include: Hanlan, Casgrain, Kendall, Lowther, Way, Devitt, and Eilber. Funding for the project was provided by the Ontario Ministry of Northern Affairs. The report is based on existing data and reports, airphoto interpretation, and field investigation.

There are an estimated 265 million tons (240 million tonnes) of sand and gravel in the Hearst Area. Approximately 147 million tons (133 million tonnes), or 55 percent of the total tonnage (most of which is sand), are currently available for extraction in the seven deposits selected for resource protection at the primary level. Only a small percentage of the primary material is crushable. The deposits are mainly buried or till-capped eskers, small kames, or buried moraines. The nature of the deposits, combined with a regionally high water table, makes aggregate assessment and extraction difficult.

The underlying bedrock consists of felsic intrusive rocks, a migmatite-metasedimentary-metavolcanic complex, diabase dikes, and metasedimentary rocks. The first three rock types are suggested for possible resource protection on the basis of drift thickness, location, and suitability for construction material. Assuming a quarriable depth of 60 feet (18 m), there are approximately 5600 million tons (5100 million tonnes) of crushable rock currently available. The high water table may make quarrying difficult and expensive.

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

AGGREGATE RESOURCE INVENTORY OF THE HEARST AREA[1]

BY
STAFF OF THE ENGINEERING
AND TERRAIN GEOLOGY SECTION

INTRODUCTION

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1981, the total tonnage of mineral aggregates extracted was 121 million tons (110 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1982).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand, gravel and crushed bedrock. The most recent information available has been used to prepare the reports. As new information becomes available, revisions may be necessary.

[1] Manuscript accepted for publication by Chief Engineering and Terrain Geology Section, March 17, 1983.
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PART I – INVENTORY METHODS

FIELD AND OFFICE METHODS

The methods used to prepare the report involved the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods included the examination of natural and man-made exposures of granular material. Most observations were made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites included estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations were also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing and hand-augering techniques were used to assess subsurface materials. Airphotos at various scales were used to determine the continuity of deposits, especially in areas where information is limited.

Deposits with potential for further extractive development or those where existing data are scarce, were studied in greater detail. Representative layers in these deposits were sampled in 25- to 100-pound (11- to 45-kg) units either from existing pit faces or from backhoe test holes. The samples were analysed for grain size distribution and in some cases for petrographic assemblage. Analyses were performed in the laboratories of the Soils and Aggregates Section, Ontario Ministry of Transportation and Communications. In areas of limited subsurface exposure, 9- to 15-foot (3- to 5-m) sections were excavated, using a wheeled backhoe. The stratigraphic section in these test holes was described and bulk samples were taken to better assess the potential of the deposit. The symbols for and locations of sample and test hole sites are noted on Map 1.

In the office, the field data were supplemented by pit information on file with the Engineering Materials Office of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The locations of additional sources were obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, were used in some areas to corroborate thickness estimates, or to indicate the presence of buried grauular material. These records were used in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a township base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3-m) thick layer of sand and gravel, one acre (0.4 ha) in extent, assuming an average density of 110 pounds per

cubic foot (1766 kg per cubic metre).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable due to the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted. The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 25 feet (8 m) of unconsolidated overburden is determined from bedrock geology maps and from the interpretation of available subsurface data. In some areas, drift thickness values were inferred from terrain units used in Engineering and Terrain Geology mapping of parts of northern Ontario. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the rock unit. In most cases a standardized estimate of a quarriable thickness of 60 feet (18 m) is used. Although the thicknesses of the Precambrian bedrock units in northern Ontario are all probably considerably greater, the 60-foot (18-m) value is considered an appropriate estimate of the maximum thickness of material that can be economically and technologically extracted from a given quarry face. Volume estimates are then multiplied by 3700, which is the estimated weight, in Imperial tons, of a one-foot (0.3-m) thick section of Precambrian granitic rock one acre (0.4 ha) in extent, assuming a bulk density of 170 pounds per cubic foot (2729 kg per cubic metre).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel as well as bedrock-derived aggregate are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976) (see Appendix B).

PART II - DATA PRESENTATION AND INTERPRETATION

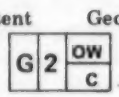
For each map area there are three maps, each portraying a different aspect of the aggregate resources in the report area. Maps 1A and 1B, "Distribution of Sand and Gravel Deposits", give a comprehensive inventory of the sand and gravel resources in the report area. Maps 2A and 2B, "Selected Sand and Gravel Resource Areas", show those deposits which are considered to represent the largest and/or highest quality resources in the area. Maps 3A and 3B, "Bedrock Resources", show the distribution of bedrock formations, the distribution of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAPS 1A and 1B: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Maps 1A and 1B are derived directly from existing surficial geology maps or from airphoto interpretation in areas where mapping is incomplete. The maps represent a comprehensive inventory of all sand and gravel deposits within the study area and serve as a base for the calculation of total sand and gravel resources. All known deposits are delineated by a dashed line and given a brown or beige tone. The present level of extractive activity is also indicated. The maps represent a summary of all available information related to the quantity and quality of aggregate in the mapped deposits. Much of this information is contained in two symbols which appear on the maps. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Maps 1A and 1B. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate makes up less than 35 percent of the whole deposit. "G" indicates that the aggregate probably contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Maps 1A and 1B.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution in deposits where samples were taken during field study. The data from which these symbols are derived has been plotted on grain size distribution graphs. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand and 10 percent silt and clay:

Test hole locations are shown on Maps 1A and 1B by a solid drill hole symbol. All known sand and gravel pits, whether presently active or inactive, are shown by a dot symbol and a number which refers to the pit descriptions given in Table 2. Each description notes the location and owner of the pit and the estimated face height and gravel content.

MAPS 2A and 2B: SELECTED SAND AND GRAVEL RESOURCE AREAS

Maps 2A and 2B are interpretative maps derived from an evaluation of the deposits shown on Maps 1A and 1B. The deposits identified on Maps 2A and 2B are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary, secondary, and tertiary. These areas are identified on Maps 2A and 2B by different shading patterns.

Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number. All such deposits are shown by a red tone on Maps 2A and 2B.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by a light red tone on the maps. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resource areas in a municipality, they may contain large quantities of sand and gravel and should be considered as an important part of the aggregate supply of the municipality.

Areas of tertiary significance are outlined on the map by a solid line but have no tone. They are neither rated nor considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

DEPOSIT SIZE

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6 m) and containing more than 35 percent crushable gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

AGGREGATE QUALITY

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Maps 1A and 1B. They are: gravel content (G or S), fines (C), oversize (O) and lithology (L).

Three of the indicators deal with grain size distribution. The gravel content, (G or S), indicates the suitability of aggregate for various

uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm seive are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of an aggregate. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock formations determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C", "O", or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Analyses of unprocessed samples obtained from test holes and pits have been plotted on grain size distribution graphs. These figures are divided into either coarse or fine aggregate graphs. The coarse aggregate graphs show samples with greater than 35 percent gravel, while the fine aggregate graphs show samples with less than 35 percent gravel. Also on the graphs are the gradation specification envelopes for Ontario Ministry of Transportation and Communications' products: Granular Base Course A, B, and C. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product.

LOCATION AND SETTING

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits and bedrock resource areas with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the

Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAPS 3A AND 3B BEDROCK RESOURCES

Maps 3A and 3B are interpretative maps derived from bedrock geology maps, water well data from the Ontario Ministry of the Environment, drilling assessment data from the Ontario Ministry of Natural Resources and from the Northern Ontario Engineering Geology Terrain Studies produced for the Ontario Geological Survey. Maps 3A and 3B are based on concepts similar to those outlined for the previous maps, but display both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Drift-covered bedrock is indicated by two blue tones and is delineated by drift thickness contour lines. The delineation of these areas has been inferred primarily from terrain units identified on Data Base Maps of the Northern Ontario Engineering Geology Terrain Studies, which exist for much of northern Ontario.

Areas where bedrock outcrops or is within 3 feet (1 m) of the ground surface are indicated by dark blue tone. Isolated bedrock outcrops which lie outside these areas are indicated by a black "X" symbol. These areas constitute potential resource areas of primary significance, because of their easy access. Areas where the bedrock is covered by 3 to 25 feet (1 to 8 m) of drift are indicated by medium blue tone. Quarrying is possible in this depth of overburden and these also represent potential resource areas. Outside the delineated areas of thin drift cover, the bedrock can be assumed to be overlain by more than 25 feet (8 m) of drift. These areas constitute resources which have extractive value only in specific circumstances and it is unlikely these areas will constitute resource areas of economic significance.

Scattered bedrock outcrops and areas of thin drift may occur in all the areas, but may not be shown on the maps due to the scale of the original mapping.

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. All known quarries are shown by a dot symbol and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, and an estimate of face height. One additional symbol appears on the map: an open dot indicates the location of a selected well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics of the bedrock units found in the study area are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of bedrock resource areas has been restricted to a single level of significance. Two factors support this approach: (1) the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material and (2) crushed bedrock has a higher unit value than sand and gravel, therefore longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The wide range of possible resource areas allows greater flexibility in locating quarry operations away from areas of intense land use competition. The selected areas are shown on Maps 3A and 3B by a line pattern and the calculated available tonnages are given in Table 6.

It should be stressed that the Precambrian Shield rocks in northern Ontario are generally more complex and variable than the Paleozoic rocks of southern Ontario. They often show wide variations in mineralogy, texture (grain size) and degree of weathering, even within specific rock types and over relatively short distances. As these factors are considered important in determining the suitability of the bedrock for use as aggregate, the aggregate potential may also vary considerably from location to location.

Careful selection is especially important if the bedrock is to be used as concrete aggregate. Deleterious chemical reactions may develop in the concrete which can lead to its eventual deterioration. Fortunately, these chemical reactions should not influence the use of bedrock-derived aggregate for hot-laid asphaltic and road base material. However, highly weathered, very porous and friable rock should be avoided for all uses.

For these reasons, the total area selected as a bedrock resource should not be considered acceptable for aggregate use. They are, however, areas in which the probability of finding a supply of acceptable aggregate is considered most likely.

Selected Bedrock Resource Areas are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

PART III - ASSESSMENT OF AGGREGATE RESOURCES IN THE HEARST AREA

LOCATION AND POPULATION

The Hearst Area covers 362,880 acres (146 858 ha) and includes the townships of Hanlan, Casgrain, Kendall, Lowther, Way, Devitt, and Eilber. The area is shown on portions of the Mead (42 G/5), Mattice (42 G/11), Hearst (42 G/12), Hanlan Lake (42 G/13), and Shannon Lake (42 G/14) map sheets of the National Topographic System, at a scale of 1:50 000.

The Town of Hearst is located in Kendall Township at the junction of King's Highway 11 and Highway 583. The population of Hearst increased 8 percent from 4998 in 1975 to 5373 in 1980 (Ontario Ministry of Intergovernmental Affairs 1981; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1976). A population decrease in Kendall Township from 405 to 365 between 1970 and 1981, and the increase in the Hearst population suggests a minor rural to urban migration.

The five townships of Hanlan, Casgrain, Kendall, Lowther, and Way are shown on Maps 1A, 2A, and 3A, and occupy a total area of 259,200 acres (104 898 ha). The combined population of Casgrain and Lowther Townships has decreased by 11 percent between 1970 and 1981 while that of Hanlan and Way Townships has increased by 38 percent (Cochrane-Timiskaming Assessment Office, personal communication, 1981).

Devitt and Eilber Townships each occupy 51,840 acres (20 980 ha) and are shown on Maps 1B, 2B, and 3B. In 1981, the townships had a total population of 349, a decrease of 35 percent since 1970 (Cochrane-Timiskaming Assessment Office, personal communication, 1981).

Each township within the area is serviced by King's Highway 11 and/or Highway 583. King's Highway 11 is the northern route of the Trans-Canada Highway. Highway 583 runs north and south from Hearst into Casgrain and Lowther Townships, respectively. A grid pattern of all-weather roads has been constructed within the periphery of the Town of Hearst.

The Hearst Area is also serviced by two major railway lines. The Canadian National Railways runs parallel to King's Highway 11 providing access to northern Ontario and southern Ontario via North Bay. The northern terminus of the Algoma Central Railway line from Sault Ste. Marie is located in Hearst.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The Hearst Area lies within the Abitibi Upland of the James Bay Region (Bostock 1970). The land surface in the study area tends to be flat or gently undulating (Lee and Scott 1980), with elevations ranging from 800 to 900 feet (244 to 274 m) above sea level.

The thickness and distribution of the unconsolidated sediments are the result of extensive glacial activity which took place during the Great Ice Age (Pleistocene Epoch). This period of time was marked by the advance and retreat of massive, continental ice sheets.

During the latter part of the Pleistocene (Late Wisconsinan Substage), the ice mass advanced, depositing a sandy till ground moraine.[2] The till is moderately compact, pale blue grey, and consists of boulders and pebbles in a sand, silt and clay matrix (Hughes 1965). Locally, the till may contain lenses of silty gravel with poorly defined bedding. These lenses range in thickness from a few inches to 15 feet (5 m) and the length may be up to 100 feet (30 m) in section (Hughes 1965). Grain size analyses carried out on samples of the till showed a significant quantity of excess fines which would limit the production of high grade aggregate. The material has been used, however, for fill and for earth dam core construction.

As the ice sheet stagnated, the major sand and gravel deposits were laid down. These include the eskers prevalent in the east-central parts of the area and the delta and ice-contact deposits in the west-central parts of the area. A moraine consisting predominantly of silty sand was also deposited in the area along the present Trans-

[2] This till is known informally as the Lower till (Hughes 1965), and as the stratigraphic equivalent to the Adam Till (Skinner 1973).

Canada Highway corridor. Ice-contact features are found on top of this moraine in Kendall and Devitt Townships. Most of these ice-contact deposits have similar characteristics, with stratified, silty fine to medium sand in the upper layers, and gravel, when present, at depth. Most of the gravel is from local Precambrian rock, but up to 25 percent chert and carbonates from the James Bay Lowlands was noted.

As the ice front continued to retreat, meltwaters were trapped between the ice front and a drift barrier to the south of the Hearst Area. These waters formed glacial Lake Barlow-Ojibway (Boissonneau 1966). The sediments deposited in this lake are known as the Barlow-Ojibway Formation. These sediments have been divided into two units: the lower made up of clay, silty clay, and silt bottom sediments; and the upper made up of silty sand, gravel, and boulders.

Following the deposition of the Barlow-Ojibway Formation, the ice sheet readvanced in a southeasterly direction over the Hearst Area (this event is known as the early phase of the Cochrane readvance). The advancing ice sheet covered the existing glacial deposits with the Cochrane till, a clay till derived from the Barlow-Ojibway sediments (Hughes 1965). This ice sheet apparently stagnated leaving a block of ice covering the southern part of Lowther Township. A second ice sheet, centred northeast of the Hearst Area, advanced in a southwesterly direction (this event is known as the late phase of the Cochrane readvance) as far as the ice block over southern Lowther Township. The ice front then rapidly melted back, allowing the meltwaters to flow north into the James Bay Lowlands. Both phases of the Cochrane readvance left a low relief, drumlinized till plain covering previously deposited glaciofluvial and ice-contact features.

Postglacial erosional and depositional processes have been of relatively minor importance in modifying the physiography of the area.

EXTRACTIVE ACTIVITY

Although more than thirty-two sand and gravel pits have been opened in the Hearst Area, many have been abandoned or have been inactive for a considerable period of time. During field investigation, eight pits were observed to be active or to have been used in the recent past. Most of these operated on an active-on-demand basis for part of the year only. Portable processing equipment is generally used. These sources supply most of the aggregate for the rural townships surrounding the Town of Hearst.

There are three quarries in the area. All three quarries have been abandoned and one is water filled.

Aggregate extraction in the study area is made difficult by a high water table and the clay till overlying most of the deposits. Sand and gravel extraction has generally been carried out by dragline operations, which are more expensive than conventional methods. An alternative would be to dewater the deposit and then mine with conventional methods, but this is also expensive. Similarly, when quarrying bedrock, the quarry would have to be dewatered. In addition, stockpiling of the clay till removed to expose aggregate sources must be done with great care to avoid slope stability problems.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Sand and gravel deposits in the Hearst Area are characteristically stratified silty sand with low stone content. Most of the deposits are capped with clay till and underlain by stratified, silty fine to medium sand.

Gravel, when present, is usually found at approximately 20 feet (6 m) below the ground surface. The water table is usually within 10 to 20 feet (3 to 6 m) of the ground surface, therefore necessitating a dragline or dewatering operation. Because the gravel is often submerged, field observations of the coarse material were limited to stockpiles and pit edges. Sampling of the gravel bearing strata was rarely possible. Numerous test holes were excavated to depths of between 10 and 15 feet (3 and 5 m). Little or no gravel was found and the sand was dirty.

The stratigraphy of the deposits tends to be as follows:

less than 1 foot (0.3 m) of topsoil;
1 to 5 feet (0.3 to 1.5 m) of Cochrane till;
10 to 15 feet (3 to 5 m) of compact Matheson till;
and coarse gravel, when present.

SELECTED SAND AND GRAVEL RESOURCE AREAS: HANLAN, CASGRAIN, KENDALL, LOWTHER, AND WAY TOWNSHIPS

Aggregate resources shown on Map 1A total approximately 194 million tons (176 million tonnes). However, resources of crushable material appear to be small. Some of the deposits containing significant quantities of sandy material may have crushable material at depth. Five of these deposits have been selected as Sand and Gravel Resource Areas of Primary Significance. Other areas have also been selected for possible resource protection, but are of secondary and tertiary significance.

The selected sand and gravel resources of primary significance occupy a total of 2030 acres (820 ha), of which 1570 acres (640 ha) are presently available for extraction. Estimated aggregate resources are 94 million tons (85 million tonnes) of mainly sandy material.

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 is an esker deposit located in north-central Hanlan Township. The deposit is a till-capped, segmented esker, with a central ridge rising sharply above the local topography.

Two pits have been opened in the deposit. Pit 1, an active source, had 35-foot (11-m) faces which revealed fine sand with some gravel. Pit 2 had a face height of 10 feet (3 m) and showed horizontally stratified, coarse to fine sand interlayered with planar cross-stratified pebbly coarse sand layers. Results of sieve analyses carried out on samples from pits 1 and 2 indicated that the material tested was predominantly sand (Figure 2). Aggregate with a higher percentage of gravel might be located deeper in the deposit. The Ontario Ministry of Transportation and Communications (M.T.C.) has suggested that 5/8 inch (16 mm) crushed stone might be produced from this source by removing the sand and fines.

Resource Area 1 has been divided into four parts. Part 1a, the esker ridge, appears to be the deepest, with an estimated thickness of 20 feet (6 m). The remaining parts of the esker are estimated to be 10 feet (3 m) thick. Cultural setbacks and previous extraction reduce the total available area to 520 acres (210 ha), containing approximately 14 million tons (13 million tonnes) of resources.

SELECTED SAND AND GRAVEL RESOURCE AREA 2

Selected Sand and Gravel Resource Area 2 is an esker ridge located in the southwest portion of Casgrain Township. The esker has been subdivided into three parts: the main esker ridge, the exposed flank, and an ice-contact delta deposit to the south of the main esker ridge.

Resource Area 2a, the esker ridge, had six pits, three of which were active. Pit faces showed the esker core to be predominantly sand with significant quantities of gravel at depths of 30 feet (9 m). Much aggregate had been extracted by dragline operations and water was observed on pit floors. Consequently, pit depths were sometimes difficult to ascertain, appearing to vary from 5 to 35 feet (1.5 to 11 m). Samples taken from pits 1 and 4 revealed varying gravel percentages (Figures 3 and 4). In general, the percentage gravel in this part of the deposit was estimated to be less than 20 percent. Two shallow test pits were dug (CA-TH-1 and CA-TH-2) in the southern part of the area, proving only sand and silty sand to a depth of 18.5 feet (5.6 m).

Resource Areas 2b and 2c form the flanks of the main esker ridge. Although there had been no extractive activity in these areas, field observations indicated that there may be gravel located at depth.

Resource Area 2 occupies a total of 1050 acres (425 ha). Cultural constraints and previous extraction reduce the area available to 840 acres (340 ha). Thickness estimates for the three parts range from 25 to 35 feet (8 to 11 m). The total resource tonnage is estimated to be 62 million tons (56 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Selected Sand and Gravel Resource Area 3 is located in the north-central part of Kendall Township, north of the Trans-Canada Highway. The deposit is part of a buried moraine which runs approximately parallel to the Trans-Canada Highway corridor.

One active pit (pit 1) was located in the area. The 5- to 35-foot (1.5- to 11-m) face exposed pebbly silty sand. Samples taken from the pit

face showed the material to have excess fines for most aggregate uses. Test pit KE-TH-1 contained more than 90 percent silt (Figure 4).

Resource Area 3 occupies a total of 205 acres (83 ha), of which 180 acres (73 ha) are presently available for aggregate extraction. Assuming a deposit thickness of 35 feet (11 m), there are approximately 16 million tons (14 million tonnes) of material suitable mainly for fill.

SELECTED SAND AND GRAVEL RESOURCE AREA 4

Selected Sand and Gravel Resource Area 4 is an ice-contact kame deposit located in the northwest corner of Lowther Township. There was one small active pit (pit 2) in the east end of the deposit. A grain size analysis performed on a sample from the pit face showed the material to be silty sand (Figure 5).

Resource Area 4 occupies 25 acres (10 ha), of which 5 acres (2 ha) are available for extraction. Assuming an average depth of 15 feet (5 m), there are less than 1 million tons (less than 1 million tonnes) of silty sand available. The material is acceptable for fill.

SELECTED SAND AND GRAVEL RESOURCE AREA 5

Selected Sand and Gravel Resource Area 5 is a till-capped, buried esker in the central part of Lowther Township. Some material has already been extracted from pit 1 which is active on demand. This source has been tested by M.T.C. and was recommended for further testing to determine acceptability for concrete or asphalt sand. Boulders observed on the pit floor indicate that there may be crushable material at depth.

Resource Area 5 occupies 60 acres (24 ha), of which 25 acres (10 ha) are available for extraction. Assuming an average depth of 30 feet (9 m), an estimated 2 million tons (2 million tonnes) of sandy material are presently available.

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

There are four deposits considered to be of secondary significance. All contain silty sand material with a possibility of gravel at depth.

The first secondary area is a buried esker ridge in Way Township. There were three inactive pits located in the deposit. In the past, pit 1 produced sand for Hot-Laid (H.L.) Nos. 4, 5, 6, and 8 aggregate. Excavated test holes WA-TH-1, 2, 3, and 4 showed the material to be silty sand with some stone (Figure 6). Additional stone may be available at depth.

The second area is a kame-esker deposit east of the primary esker deposit in Casgrain Township. The southern part of the deposit has the appearance of a circular mound similar to a kame while the northern part of the deposit is esker-like. Test holes CA-TH-4 and CA-TH-5 showed the material to be silty sand (Figure 3c).

The third deposit of secondary significance is the apron of material around Resource Area 3 in Kendall Township. Although there was no subsurface data for this area, airphoto interpretation and field observations indicated a fairly thick sand deposit. This deposit may be part of a local moraine.

The last deposit of secondary significance is a small kame along the east boundary of Kendall Township. This deposit contained one depleted pit. Resources are limited.

SELECTED SAND AND GRAVEL RESOURCE AREAS: DEVITT AND EILBER TOWNSHIPS

There are two deposits of primary significance in Devitt and Eilber Townships; one west of the Missinaibi River and a second in the southeast corner of Eilber Township. There is also one small secondary area at the western boundary of Devitt Township.

The total area covered by primary aggregate deposits in this portion of the Hearst Area is approximately 940 acres (380 ha), of which 700 acres (285 ha) are currently available for extraction. Assuming an average thickness for each deposit, estimated resources are 53 million tons (48 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 is a buried esker located along the border between Devitt and Eilber Townships. This esker is the primary source of crushable material in the Hearst Area. The deposit has been divided into three parts: the lower esker ridge; and two areas of thicker material, one at each end of the deposit area.

Area 1a is a buried ridge within the esker in Devitt Township. Crushable material has previously been extracted from one large pit (pit 1) and used locally to produce concrete and asphalt. The ridge is estimated to be 50 feet (15 m) thick, with 20 feet (6 m) of silty sand overlying approximately 30 feet (9 m) of sand and gravel.

Area 1c is an exposed ridge at the northern end of the esker in Eilber Township. This area had one shallow, active pit (pit 1). A sample from the pit face showed the material in the pit to be silty sand (Figure 8). The 12-foot (4-m) face showed only trace gravel. However, gravel may be found at depth as in Area 1a. Consequently, the deposit thickness is estimated to be 35 feet (11 m).

Area 1b consists of the remainder of the mapped esker. There were two inactive pits in the area and both appear to have produced coarse material (pits 2 and 3). Oversize material was found on the floor of pit 2 and data provided by M.T.C. confirmed a gravel content of 35 to 40 percent. Both pits were abandoned and overgrown. This part of the deposit is estimated to be 30 feet (9 m) thick.

Resource Area 1 occupies a total of 720 acres (290 ha), of which 520 acres (210 ha) are currently available. Approximately 44 million tons (40 million tonnes) of sand and gravel are available for extraction.

SELECTED SAND AND GRAVEL RESOURCE AREA 2

Selected Sand and Gravel Resource Area 2 is an esker located in the southeast corner of Eilber Township. The esker is mostly buried with an exposed ridge at the northeast end of the deposit. The esker has been subdivided into two parts, the exposed ridge and the remainder of the esker.

Area 2a had one inactive pit (pit 6) with a face height of 45 feet (14 m). The floor was covered by water, making further field observation difficult. A dragline operation was once used in the pit. Therefore, coarse material may still be available at depth.

Area 2b, the remainder of the mapped esker, had two abandoned sand pits, both with faces of less than 12 feet (4 m) (pits 4 and 5). Samples from these pits showed the material to be silty sand to sand with some silt (Figure 8). Coarse aggregate may be available at depth.

Resource Area 2 covers a total of 225 acres (91 ha), of which 180 acres (73 ha) are currently available. An estimated 9 million tons (8 million tonnes) of sandy aggregate are present.

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

The only area suggested as a Sand and Gravel Resource Area of Secondary Significance is located at the western boundary of Devitt Township. The deposit is a continuation of the small kame found in Kendall Township. The material is largely silty sand acceptable for fill.

BEDROCK GEOLOGY

The Hearst Area lies in the southern part of the Superior Province of the Precambrian Canadian Shield. The bedrock consists of: biotite-quartz-feldspar gneiss and hornblende-quartz-feldspar gneiss which are part of a migmatite-metasedimentary-metavolcanic complex (Rock Type A); granitic intrusive rocks including granodiorite, quartz monzonite, granite, and granite pegmatite (Rock Type B); and metasedimentary rocks consisting of quartz-feldspar greywacke (Rock Type C). Diabase dikes (Rock Type D) of undetermined widths cross the three rock types (Bennett et al. 1967a). Bedrock topography appears to be irregular and drift thickness is variable.

Rock Type A is composed of felsic intrusive rocks in large batholiths, satellite stocks, and lit-par-lit injection layers in the gneiss complex. These rocks vary in composition from granite to quartz monzonite to granodiorite. The grain size ranges from fine to coarse (Bennett et al. 1967a).

Although this type of rock has not been quarried within the Hearst Area, a similar rock type has been quarried elsewhere in the region and was found to produce acceptable granular products. However, as with Type B rocks, there may be problems with popping, and alkali-silica reaction. A detailed petrographic examination should be carried out before the material is quarried.

Rock Type B consists of the migmatite-metasedimentary-metavolcanic complex. These

rocks have a wide range of composition and metamorphic structure. The biotite-quartz-feldspar gneiss and the biotite-feldspar gneiss exhibit similar gradations in their compositional, textural, and structural characteristics. Gneissic banding varies from biotite schist or amphibolite layers separated by massive quartz-feldspar layers to regularly banded gneiss (Bennett et al. 1967a).

There are two quarries located in this rock type. The M.T.C. has tested crushed stone from a Type B outcrop west of Hearst and found the material acceptable for granular products used in highway construction. However, because of variability within the rock type and anticipated problems associated with stripping and popping, and alkali-silica reaction, more detailed petrographic investigations may be required before commercial quarry sites are selected.

A small area of Type C metasedimentary rocks is located in the southern part of Lowther Township. These rocks consist primarily of quartz-feldspar greywacke. Secondary mineralization, consisting of biotite, chlorite, and sericite, makes these rocks unsuitable sources of construction material.

Rock Type D consists of diabase dikes which cut through the older Type A, B, and C rocks. The diabase varies in texture from a fine-grained diabase to a coarse-grained gabbroic material and is generally acceptable for crushed stone products. One quarry, partially located in this rock type produced road-building materials in the past. The width of the dikes has not been determined.

SELECTED BEDROCK RESOURCE AREAS: HANLAN, CASGRAIN, KENDALL, LOWTHER, AND WAY TOWNSHIPS

Four areas of Rock Types A and B, including diabase dikes, have been selected for possible resource protection in the townships of Hanlan, Casgrain, Kendall, Lowther, and Way. Drift cover is generally less than 25 feet (8 m) thick.

The Selected Bedrock Resource Areas occupy a total of 14,400 acres (5800 ha), of which 11,900 acres (4800 ha) are available for extractive development. Assuming a quarriable depth of 60 feet (18 m), an estimated 2650 million tons (2400 million tonnes) of crushed stone are available for the production of aggregate products.

SELECTED BEDROCK RESOURCE AREA 1

Selected Bedrock Resource Area 1 is located in the eastern part of Kendall Township. The area is generally flat, tree covered, and has good access. Part of the area consists of developed land associated with the railway, highway, and village of Hallebourg.

Resource Area 1 contains 65 acres (26 ha) of Type A rock with less than 3 feet (1 m) of overburden. After deletions for cultural setbacks, approximately 45 acres (18 ha) are available for extractive activity. Assuming a quarriable depth of 60 feet (18 m), there are approximately 10 million tons (9 million tonnes) of crushed stone resources.

The remainder of the area, 1670 acres (680 ha), consists of Types A and B rocks. Drift cover ranges from 3 to 25 feet (1 to 8 m) in depth. After deletions for cultural setbacks, approximately 1490 acres (600 ha) are available for extractive activity. Assuming a quarriable depth of 60 feet (18 m), resources of crushed stone are estimated to be 330 million tons (300 million tonnes).

SELECTED BEDROCK RESOURCE AREA 2

Selected Bedrock Resource Area 2 surrounds Pivabiska Lake in Hanlan and Casgrain Townships. The area is relatively flat and swampy. Access is provided by township and logging roads via Highway 583.

The resource area consists primarily of Type B rocks with minor areas of Type A rocks and diabase dikes. Along the shores of Lake Pivabiska, there are small areas where the bedrock is covered by less than 3 feet (1 m) of drift. However, for the most part, the drift cover ranges from 3 to 25 feet (1 to 8 m).

Approximately 135 acres (55 ha) of the bedrock has less than 3 feet (1 m) of drift cover. Cultural setbacks associated with the lake reduce this area to approximately 105 acres (42 ha). Assuming a quarriable depth of 60 feet (18 m), approximately 23 million tons (21 million tonnes) of bedrock are available for the production of crushed stone products.

The greatest part of the resource area, 8800 acres (3550 ha), is covered by 3 to 25 feet (1 to 8 m) of drift. An estimated 7000 acres (2850 ha) are currently available for extraction. Assuming a quarriable depth of 60 feet (18 m), crushed stone resources are approximately 1540 million tons (1400 million tonnes).

SELECTED BEDROCK RESOURCE AREA 3

Selected Bedrock Resource Area 3 is located in the northwest corner of Hanlan Township. The area consists of Types A and B rocks. The drift cover is generally 3 to 25 feet (1 to 8 m) thick. The area is densely vegetated and is accessible only by logging roads.

The resource area occupies 1220 acres (495 ha), of which 1060 acres (430 ha) are available for extraction. Assuming a quarriable depth of 60 feet (18 m), there are approximately 235 million tons (213 million tonnes) of crushed stone available.

SELECTED BEDROCK RESOURCE AREA 4

Selected Bedrock Resource Area 4 consists of two areas of Type A rocks overlain by 3 to 25 feet (1 to 8 m) of drift. One area is located in the central part of Lowther Township and the other is located to the north, along the Lowther-Way boundary. Access to the northern part of the deposit is provided by township and bush roads and the Algoma Central Railway. Access to the southern area is by township and winter roads. The southern area is crossed by diabase dikes.

Resource Area 4 occupies a total of 2500 acres (1010 ha), of which 2220 acres (900 ha) are presently available for extraction. Assuming a quarriable depth of 60 feet (18 m), an estimated 495 million tons (450 million tonnes) of crushed stone are available.

SELECTED BEDROCK RESOURCE AREAS: DEVITT AND EILBER TOWNSHIPS

Three Selected Bedrock Resource Areas are located in Devitt and Eilber Townships. The bedrock resources consist primarily of Type B rocks. The drift cover is generally 3 to 25 feet (1 to 8 m) thick. A small area in Devitt Township with drift thickness of less than 3 feet (1 m) has been quarried in the past. The quarry is now water filled and abandoned.

SELECTED BEDROCK RESOURCE AREA 1

Selected Bedrock Resource Area 1 is a continuation of the resource area in Kendall Township. Access to the area is limited to the north end of the area, where King's Highway 11 and the Canadian National Railways cross the deposit. There is no access to the southern part of the deposit.

Approximately 135 acres (55 ha) of bedrock are covered by less than 3 feet (1 m) of drift. One hundred and ten acres (44 ha) are currently available for extractive purposes. Assuming a quarriable depth of 60 feet (18 m), an estimated 24 million tons (22 million tonnes) of crushed stone are available.

An estimated 3500 acres (1420 ha) of this resource area have 3 to 25 feet (1 to 8 m) of drift cover. After deletions for cultural setbacks approximately 3350 acres (1360 ha) remain for extractive purposes. Assuming a workable depth of 60 feet (18 m), crushed stone resources total 740 million tons (670 million tonnes).

SELECTED BEDROCK RESOURCE AREA 2

Selected Bedrock Resource Area 2 is located in the southern portion of Devitt Township. Access to the area is provided by one township road extending south from the Trans-Canada Highway. The resource area consists of Type B rocks and has 3 to 25 feet (1 to 8 m) of overburden.

Resource Area 2 covers 1100 acres (445 ha), of which 1060 acres (430 ha) are presently available for extractive purposes. Assuming a workable depth of 60 feet (18 m), an estimated 235 million tons (213 million tonnes) of crushed stone are available.

SELECTED BEDROCK RESOURCE AREA 3

Selected Bedrock Resource Area 3 is located in the western part of Devitt and the eastern part of Eilber Township. The area consists primarily of Type B rocks, covered with 3 to 25 feet (1 to 8 m) of overburden. Access is provided by the Trans-Canada Highway and the Canadian National Railways.

Resource Area 3 covers 10,500 acres (4250 ha), of which 9100 acres (3700 ha) are presently available for extraction. Assuming a quarriable

depth of 60 feet (18 m), an estimated 2020 million tons (1830 million tonnes) of rock are available for crushing and aggregate use.

SUMMARY

Sand and gravel resources in the Hearst Area consist of silty sand deposits extending to a depth of 20 feet (6 m) or greater. Good quality gravel, where present, is generally found at depth below the water table necessitating dragline extraction techniques and extensive stripping operations. The deposits are generally till capped or completely buried by younger formations.

The underlying bedrock is generally acceptable for the production of construction material. However, the regionally high water table inhibits quarrying without dewatering in all but a few locations where the bedrock occurs in knobs above the local terrain.

Enquiries regarding the Aggregate Resources Inventory of the Hearst Area should be directed to the Ontario Ministry of Natural Resources, either at the Hearst District Office, Box 670, Hearst, Ontario, P0L 1N0 (Tel. (705) 362-4346) or at the Northern Region Office, 60 Wilson Avenue, Timmins, Ontario, P4N 2S7 (Tel. (705) 267-1401).

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, HEARST AREA

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
HANLAN TOWNSHIP			
1	S-E	70 (28)	4 (4)
	S-IC	160 (65)	8 (7)
2	S-E	620 (250)	16 (14)
3	S-IC	72 (29)	1 (1)
4	S-E	110 (44)	1 (1)
	S-IC	72 (29)	<1 (<1)
		1100 (445)	30 (27)
CASGRAIN TOWNSHIP			
1	S-E	800 (325)	62 (56)
	S-IC-LD	245 (99)	15 (14)
2	S-K-E	285 (115)	11 (10)
3	S-E	189 (76)	<1 (<1)
4	S-E	430 (174)	2 (2)
		1950 (790)	90 (82)

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, HEARST AREA

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
KENDALL TOWNSHIP			
1	S-IC	485 (196)	40 (36)
2	S-K	15 (6)	<1 (<1)
4	S-E	110 (44)	1 (1)
		610 (247)	41 (37)
LOWTHER TOWNSHIP			
1	S-E	60 (24)	4 (4)
2	S-IC	25 (10)	1 (1)
		85 (34)	5 (4)
WAY TOWNSHIP			
1	S-E	385 (156)	19 (17)
	S-IC	140 (57)	7 (6)
4	S-IC	180 (73)	2 (2)
		700 (285)	28 (25)
	Total Map 1A	4450 (1800)	194 (176)

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, HEARST AREA

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
DEVITT TOWNSHIP			
1	S-E	480 (194)	45 (41)
2	S-K	20 (8)	<1 (<1)
		500 (202)	45 (41)
EILBER TOWNSHIP			
1	S-E	275 (111)	21 (19)
2	S-E	185 (75)	7 (6)
		460 (186)	28 (25)
	Total Map 1B	960 (390)	73 (66)

TABLE 2 | SAND AND GRAVEL PITS, HEARST AREA

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 FACE HEIGHT Feet (Metres)	7 % GRAVEL	8 PIT STATUS
HANLAN TOWNSHIP							
1	HL15-1	M.T.C.	14	7	35 (11)		
2	–	Unknown	–	6	10 (3)	10	
3	–	Unknown	7	8-9	5 (1.5)		
4	–	Unknown	8-9	9	5 (1.5)		
CASGRAIN TOWNSHIP							
1	H13-6	M.T.C.	24	4	15-25 (5-8)	<20	
2	HL15-3	Gaston Poulin	23	4	25 (8)		
3	HL15-2	M.T.C.	25	3	15-20 (5-6)		
4	HL15-6	Kolvisto	22	5	15-20 (5-6)	10-25	
5	HL15-5	Komulainen	21	5	5-15 (1.5-5)		
6	HL15-4	Boutin	23	5	5-35 (1.5-11)		
KENDALL TOWNSHIP							
1	H13-3	Pominville	14	10	5-35 (1.5-11)		
2	H27-1	Unknown	1	8	15 (5)		depleted
3	–	M.T.C.	28-29	2	5 (1.5)		

TABLE 2 | SAND AND GRAVEL PITS, HEARST AREA

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 FACE HEIGHT Feet (Metres)	7 % GRAVEL	8 PIT STATUS
LOWTHER TOWNSHIP							
1	H13-5	Coppel Pit (Quarry Permit from M.T.C.)	E½16	8	10-25 (3-8)		
2	–	Unknown	19	11	–		
3	–	Unknown	14	8	12 (4)		
4	H13-17	Unknown	18	11	3-5 (1-1.5)		
WAY TOWNSHIP							
1	H13-12	Daigle and Dillon	12	3-4	12-15 (4-5)		
2	–	Unknown	15	2-3	15 (5)		
3	–	Unknown	12	3	--		
DEVITT TOWNSHIP							
1	M27-27	LaBelle	3	5	–		
2	M27-10	Dallaire	1	6	5-25 (1.5-8)	35-40	overgrown
3	M27-19	Lachance and Nadeau	3-4	4	–	35-40	overgrown
4	M27-9	Doven	11	5	5 (1.5)		
5	–	Unknown	12	6-7	5 (1.5)		
6	M27-17	Gouley	15	6	–		

TABLE 2 | SAND AND GRAVEL PITS, HEARST AREA

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 FACE HEIGHT Feet (Metres)	7 % GRAVEL	8 PIT STATUS
EILBER TOWNSHIP							
1	M27-18	Chabot	27	7	12 (4)		
2	–	Breton	25	5	–		
3	M27-2	Christianson	26	4	10 (3)		
4	M27-15	Goulet	7-8	1	<10 (<3)		
5	M27-5	Sharles	6	1	<12 (<4)		
6	–	Carty	6-7	1	45 (14)		

TABLE 3 | SELECTED SAND AND GRAVEL RESOURCE AREAS, HEARST AREA

1 DEPOSIT NO.	2 AREA Acres (Hectares)	3 CULTURAL SETBACKS Acres (Hectares)	4 EXTRACTED AREA Acres (Hectares)	5 AVAILABLE AREA Acres (Hectares)	6 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	7 AVAILABLE AGGREGATE Millions of Tons (Tonnes)
HANLAN TOWNSHIP						
1a	70 (28)	25 (10)	5 (2)	40 (16)	20 (6)	2 (2)
1b	340 (138)	30 (12)	0 (0)	310 (126)	10 (3)	8 (7)
1c	150 (61)	50 (20)	0 (0)	100 (40)	10 (3)	2 (2)
1d	130 (53)	60 (24)	0 (0)	70 (28)	10 (3)	2 (2)
	690 (280)	165 (67)	5 (2)	520 (210)		14 (13)
CASGRAIN TOWNSHIP						
2a	530 (214)	60 (24)	70 (28)	400 (162)	35 (11)	35 (32)
2b	275 (111)	75 (30)	0 (0)	200 (81)	25 (8)	12 (11)
2c	245 (99)	10 (4)	0 (0)	235 (95)	25 (8)	15 (14)
	1050 (425)	145 (59)	70 (28)	840 (340)		62 (56)
KENDALL TOWNSHIP						
3	205 (83)	15 (6)	10 (4)	180 (73)	35 (11)	16 (14)
LOWTHER TOWNSHIP						
4	25 (10)	15 (6)	5 (2)	5 (2)	15 (5)	<1 (<1)
5	60 (24)	30 (12)	5 (2)	25 (10)	30 (9)	2 (2)
	85 (34)	45 (18)	10 (4)	30 (12)		2 (2)
Total Map 2A	2030 (820)	370 (150)	95 (38)	1570 (640)		94 (85)

TABLE 3 | SELECTED SAND AND GRAVEL RESOURCE AREAS, HEARST AREA

1 DEPOSIT NO.	2 AREA Acres (Hectares)	3 CULTURAL SETBACKS Acres (Hectares)	4 EXTRACTED AREA Acres (Hectares)	5 AVAILABLE AREA Acres (Hectares)	6 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	7 AVAILABLE AGGREGATE Millions of Tons (Tonnes)
WAY TOWNSHIP						
			– NONE –			
DEVITT TOWNSHIP						
1a	110 (44)	25 (10)	5 (2)	80 (32)	50 (15)	10 (9)
1b	370 (150)	95 (38)	5 (2)	270 (109)	30 (9)	20 (18)
	480 (194)	120 (49)	10 (4)	350 (142)		30 (27)
EILBER TOWNSHIP						
1b	185 (75)	40 (16)	15 (6)	130 (53)	30 (9)	10 (9)
1c	50 (20)	0 (0)	10 (4)	40 (16)	35 (11)	4 (4)
2a	40 (16)	0 (0)	5 (2)	35 (14)	40 (12)	4 (4)
2b	185 (75)	35 (14)	5 (2)	145 (59)	15 (5)	5 (4)
	460 (186)	75 (30)	35 (14)	350 (142)		23 (21)
Total Map 2B	940 (380)	195 (79)	45 (18)	700 (285)		53 (48)

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, HEARST AREA

1 DRIFT THICKNESS Feet (Metres)	2 BEDROCK LITHOLOGY	3 QUARRIABLE THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
HANLAN TOWNSHIP				
3-25 (1-8)	Type A	60 (18)	560 (227)	125 (113)
0-3 (0-1)	Type B	60 (18)	135 (55)	30 (27)
3-25 (1-8)	Type B	60 (18)	7500 (3050)	1660 (1510)
			7600 (3100)	1690 (1530)
		Total	8200 (3300)	1820 (1650)
CASGRAIN TOWNSHIP				
3-25 (1-8)	Type A	60 (18)	70 (28)	16 (14)
3-25 (1-8)	Type B	60 (18)	2800 (1130)	620 (560)
		Total	2850 (1150)	640 (580)
KENDALL TOWNSHIP				
0-3 (0-1)	Type A	60 (18)	65 (26)	14 (13)
3-25 (1-8)	Type A	60 (18)	1340 (540)	300 (270)
			1400 (570)	315 (285)
3-25 (1-8)	Type B	60 (18)	1590 (640)	355 (320)
		Total	3000 (1210)	670 (610)

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, HEARST AREA

1 DRIFT THICKNESS Feet (Metres)	2 BEDROCK LITHOLOGY	3 QUARRIABLE THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
LOWTHER TOWNSHIP				
3-25 (1-8)	Type A	60 (18)	2380 (960)	530 (480)
3-25 (1-8)	Type B	60 (18)	550 (223)	122 (111)
		Total	2950 (1190)	650 (590)
WAY TOWNSHIP				
3-25 (1-8)	Type A	60 (18)	495 (200)	110 (100)
		Total Map 3A	17,500 (7100)	3900 (3550)
DEVITT TOWNSHIP				
3-25 (1-8)	Type A	60 (18)	940 (380)	209 (190)
0-3 (0-1)	Type B	60 (18)	135 (55)	30 (27)
3-25 (1-8)	Type B	60 (18)	12,600 (5100)	2800 (2550)
		Total	13,600 (5500)	3050 (2750)
EILBER TOWNSHIP				
3-25 (1-8)	Type B	60 (18)	1700 (690)	375 (340)
		Total Map 3B	15,300 (6200)	3400 (3100)

TABLE 5 | QUARRIES, HEARST AREA

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 FACE HEIGHT Feet (Metres)	7 QUARRY STATUS
HANLAN TOWNSHIP						
		– NONE –				
CASGRAIN TOWNSHIP						
		– NONE –				
KENDALL TOWNSHIP						
1	H13-8	Klimack	10	9 (S)		
2	H13-7	Thompson	11	10	15-25 (5-8)	
LOWTHER TOWNSHIP						
		– NONE –				
WAY TOWNSHIP						
		– NONE –				
DEVITT TOWNSHIP						
1	M27-21	Lachance	E½24	6		water filled
EILBER TOWNSHIP						
		– NONE –				

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, HEARST AREA

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED QUARRIABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
KENDALL TOWNSHIP							
1	0-3 (0-1)	65 (26)	20 (8)	0 (0)	45 (18)	60 (18)	10 (9)
	3-25 (1-8)	1670 (680)	180 (73)	0 (0)	1490 (600)	60 (18)	330 (300)
		1740 (700)	200 (81)	0 (0)	1540 (620)		340 (310)
HANLAN TOWNSHIP							
2	0-3 (0-1)	135 (55)	30 (12)	0 (0)	105 (42)	60 (18)	23 (21)
	3-25 (1-8)	6200 (2500)	1700 (690)	0 (0)	4500 (1820)	60 (18)	1000 (910)
		6300 (2550)	1730 (700)	0 (0)	4600 (1860)		1020 (920)
3	3-25 (1-8)	1220 (495)	160 (65)	0 (0)	1060 (430)	60 (18)	235 (213)
		7500 (3050)	1890 (760)	0 (0)	5700 (2310)		1260 (1140)
CASGRAIN TOWNSHIP							
2	3-25 (1-8)	2650 (1070)	200 (81)	0 (0)	2450 (990)	60 (18)	540 (490)

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, HEARST AREA

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED QUARRIABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
LOWTHER TOWNSHIP							
4	3-25 (1-8)	2030 (820)	170 (69)	0 (0)	1860 (750)	60 (18)	415 (375)
WAY TOWNSHIP							
4	3-25 (1-8)	495 (200)	135 (55)	0 (0)	360 (146)	60 (18)	80 (73)
	Total Map 3A	14,400 (5800)	2600 (1050)	0 (0)	11,900 (4800)		2650 (2400)
DEVITT TOWNSHIP							
1	0-3 (0-1)	135 (55)	20 (8)	5 (2)	110 (44)	60 (18)	24 (22)
	3-25 (1-8)	3500 (1420)	150 (61)	0 (0)	3350 (1360)	60 (18)	740 (670)
		3650 (1480)	170 (69)	5 (2)	3450 (1400)		760 (690)
2	3-25 (1-8)	1100 (445)	40 (16)	0 (0)	1060 (430)	60 (18)	235 (213)
3	3-25 (1-8)	8800 (3550)	900 (365)	0 (0)	7900 (3200)	60 (18)	1750 (1590)
		13,600 (5500)	1110 (450)	5 (2)	12,400 (5000)		2750 (2500)

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, HEARST AREA

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED QUARRIABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
EILBER TOWNSHIP							
3	3-25 (1-8)	1700 (690)	500 (202)	0 (0)	1200 (485)	60 (18)	265 (240)
	Total Map 3B	15,300 (6200)	1610 (650)	5 (2)	13,600 (5500)		3000 (2700)

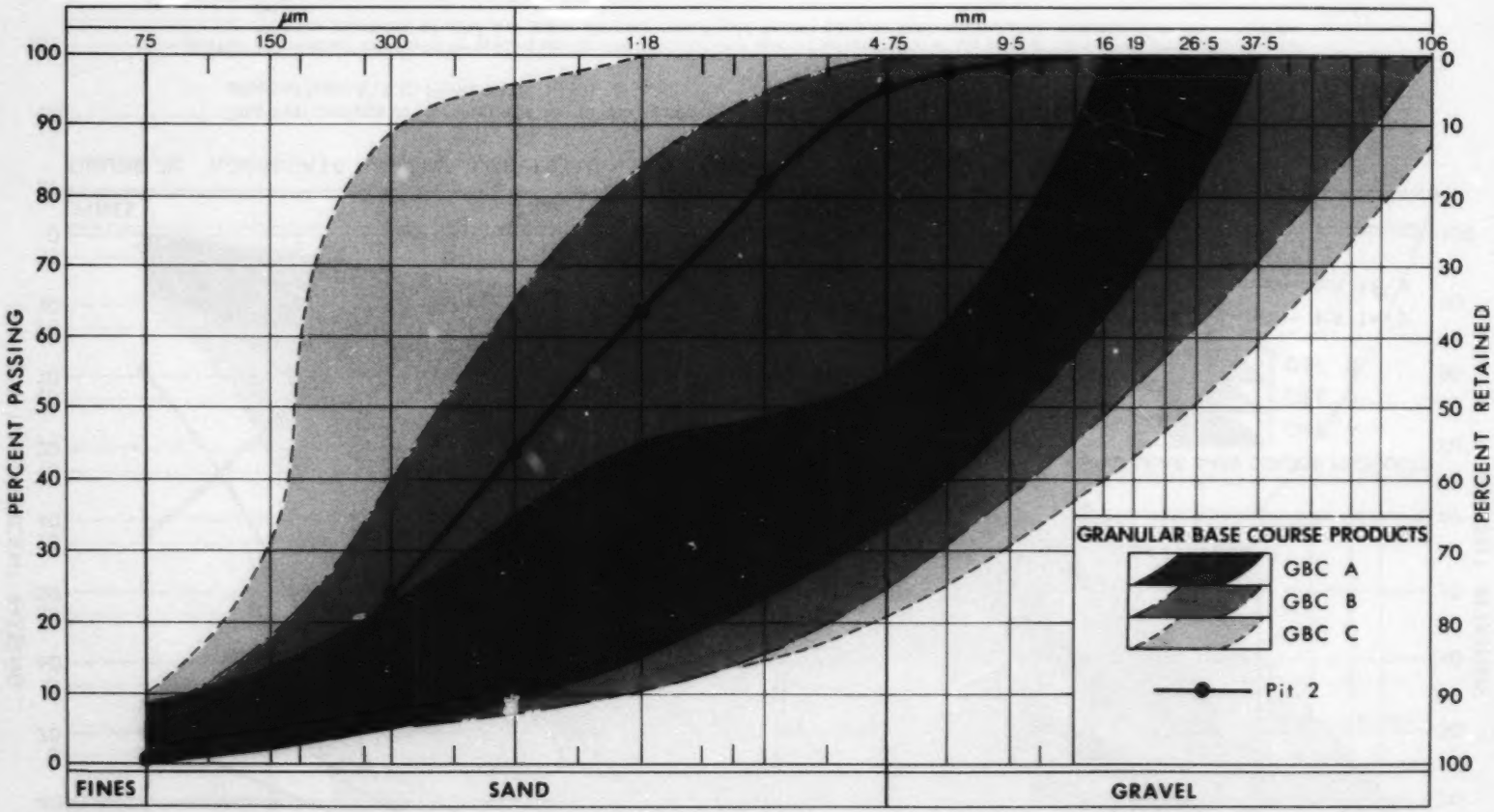


FIGURE 2a: AGGREGATE GRADING CURVES, HANLAN TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

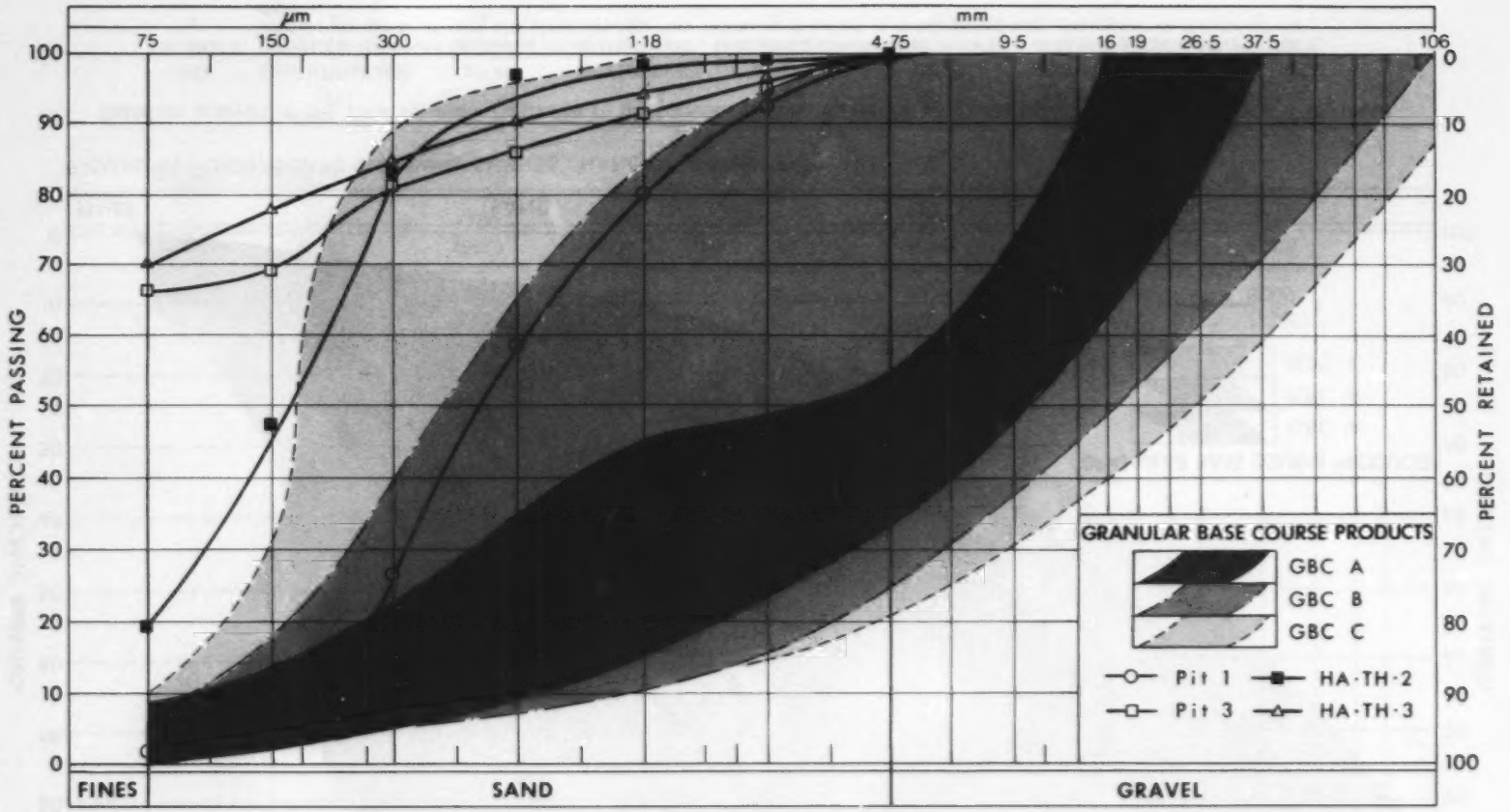


FIGURE 2b: AGGREGATE GRADING CURVES, HANLAN TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

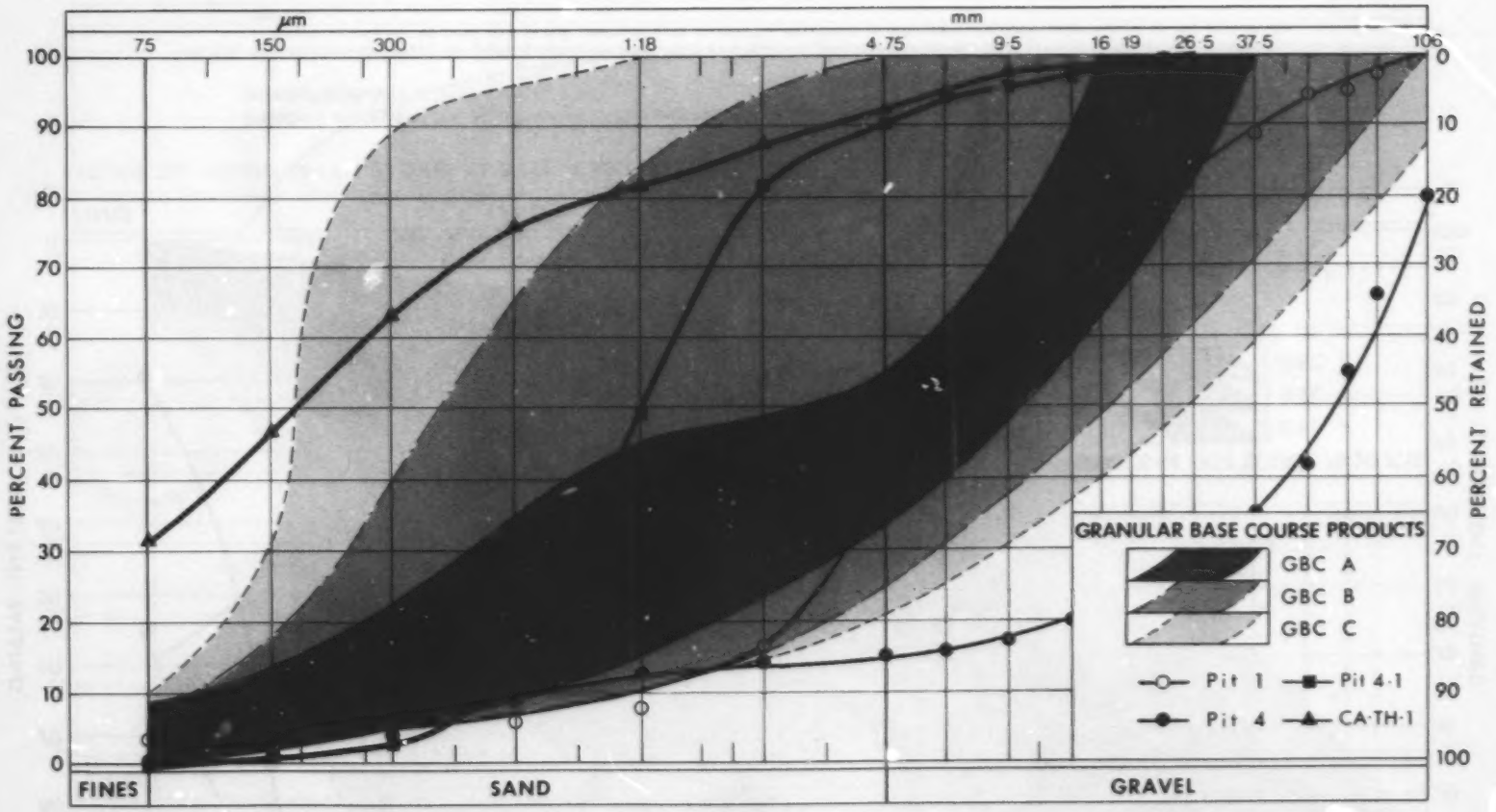


FIGURE 3a: AGGREGATE GRADING CURVES, CASGRAIN TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

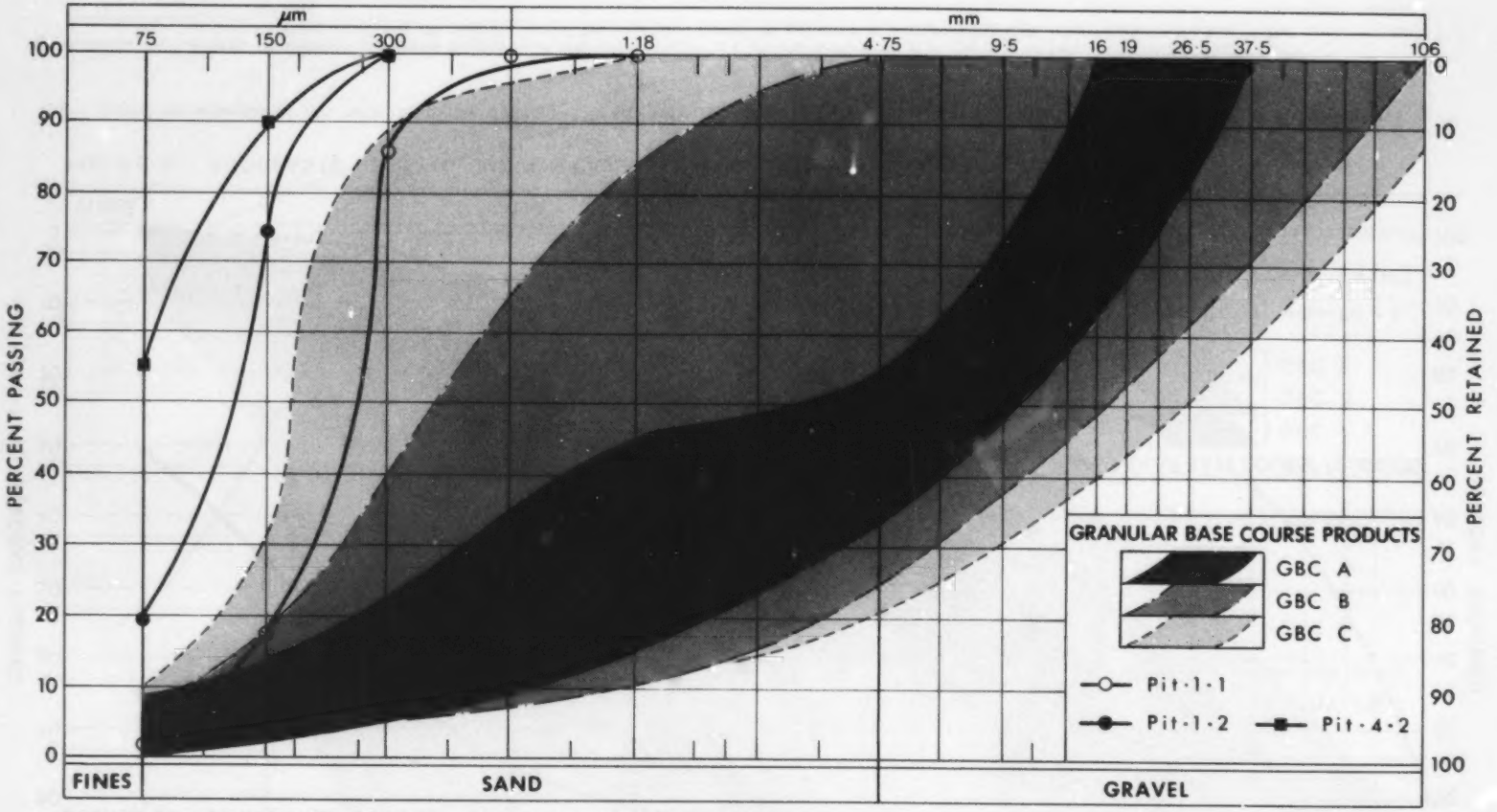


FIGURE 3b: AGGREGATE GRADING CURVES, CASGRAIN TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

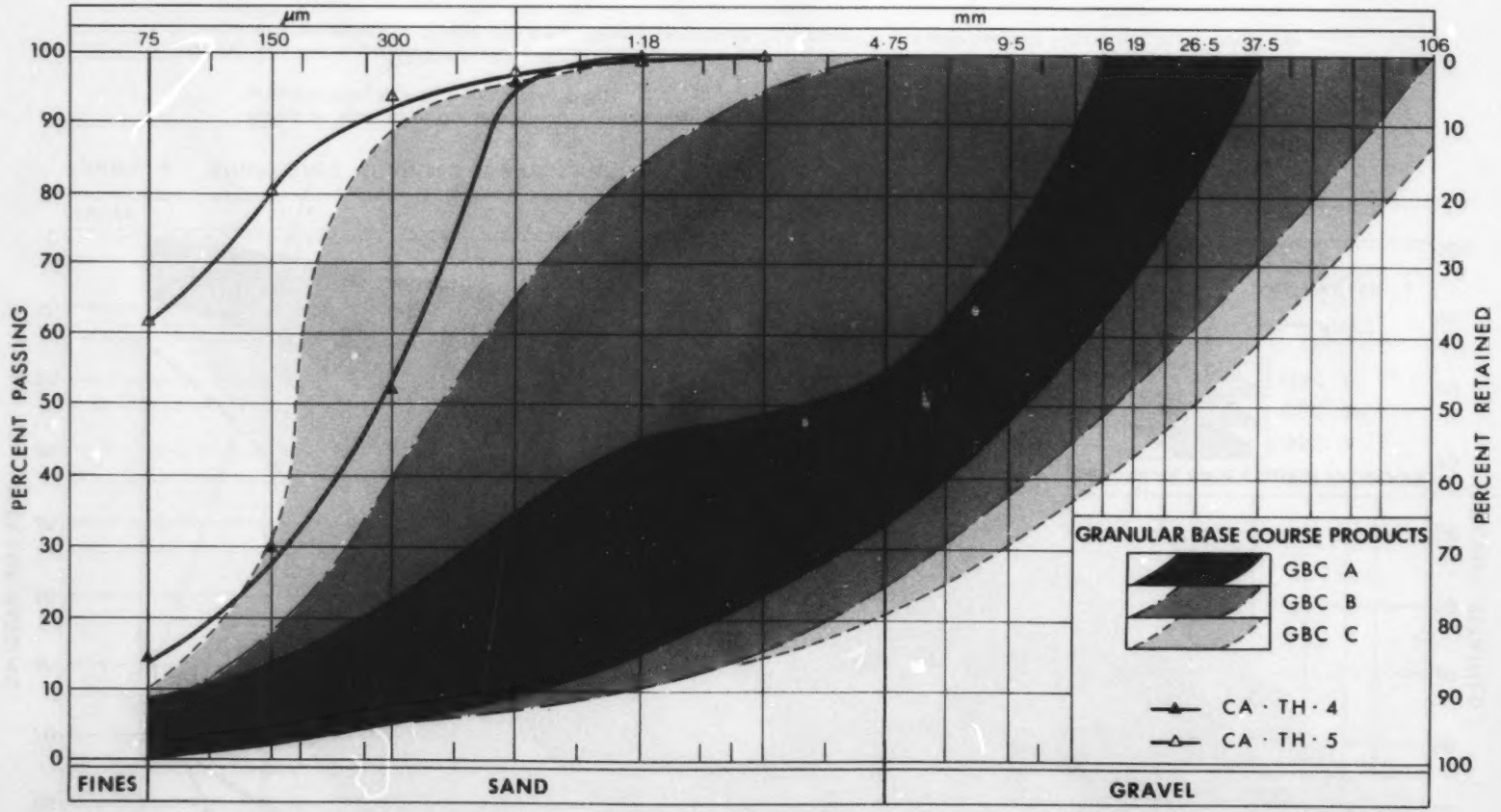


FIGURE 3c: AGGREGATE GRADING CURVES, CASGRAIN TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

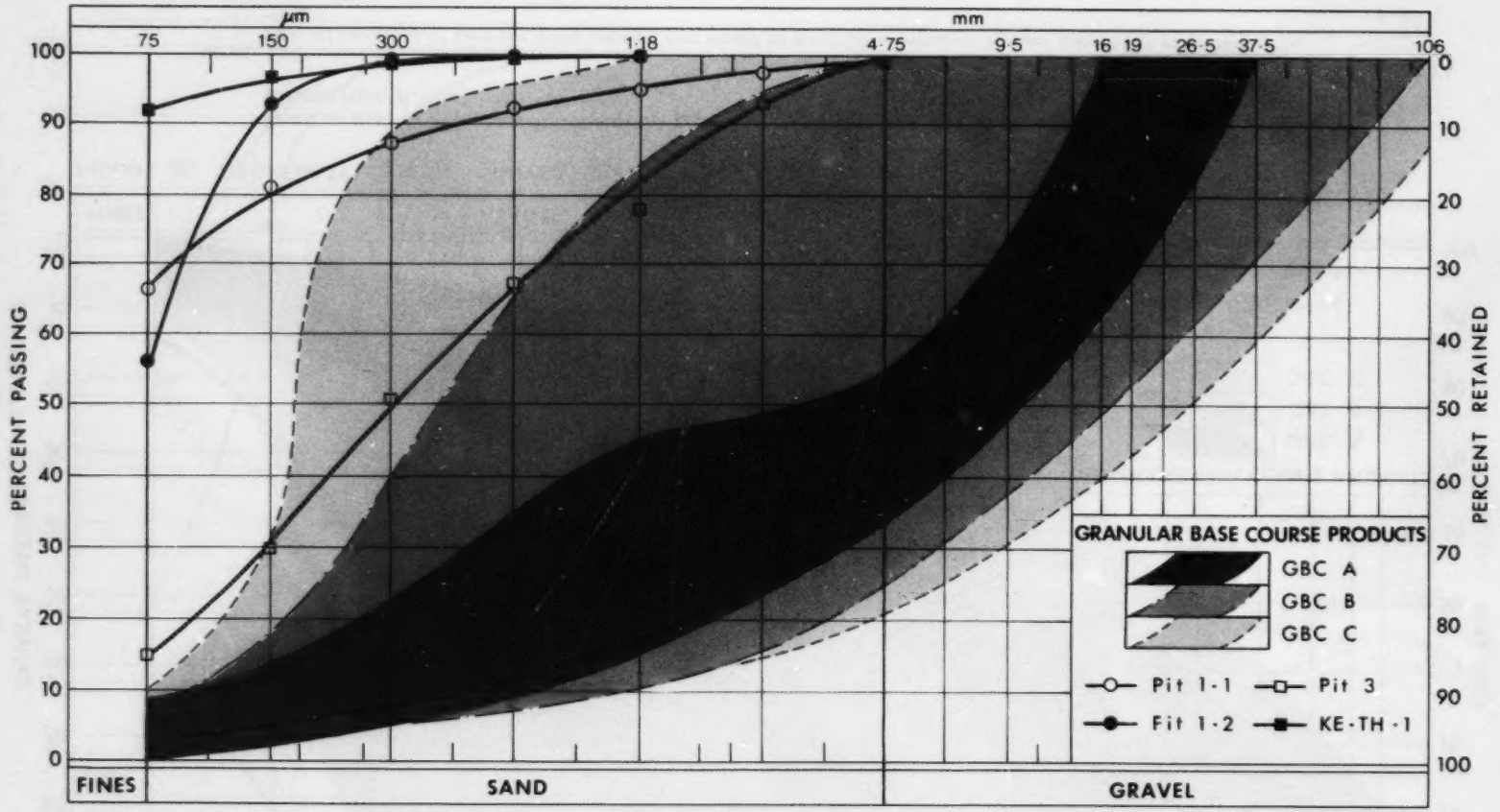


FIGURE 4: AGGREGATE GRADING CURVES, KENDALL TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

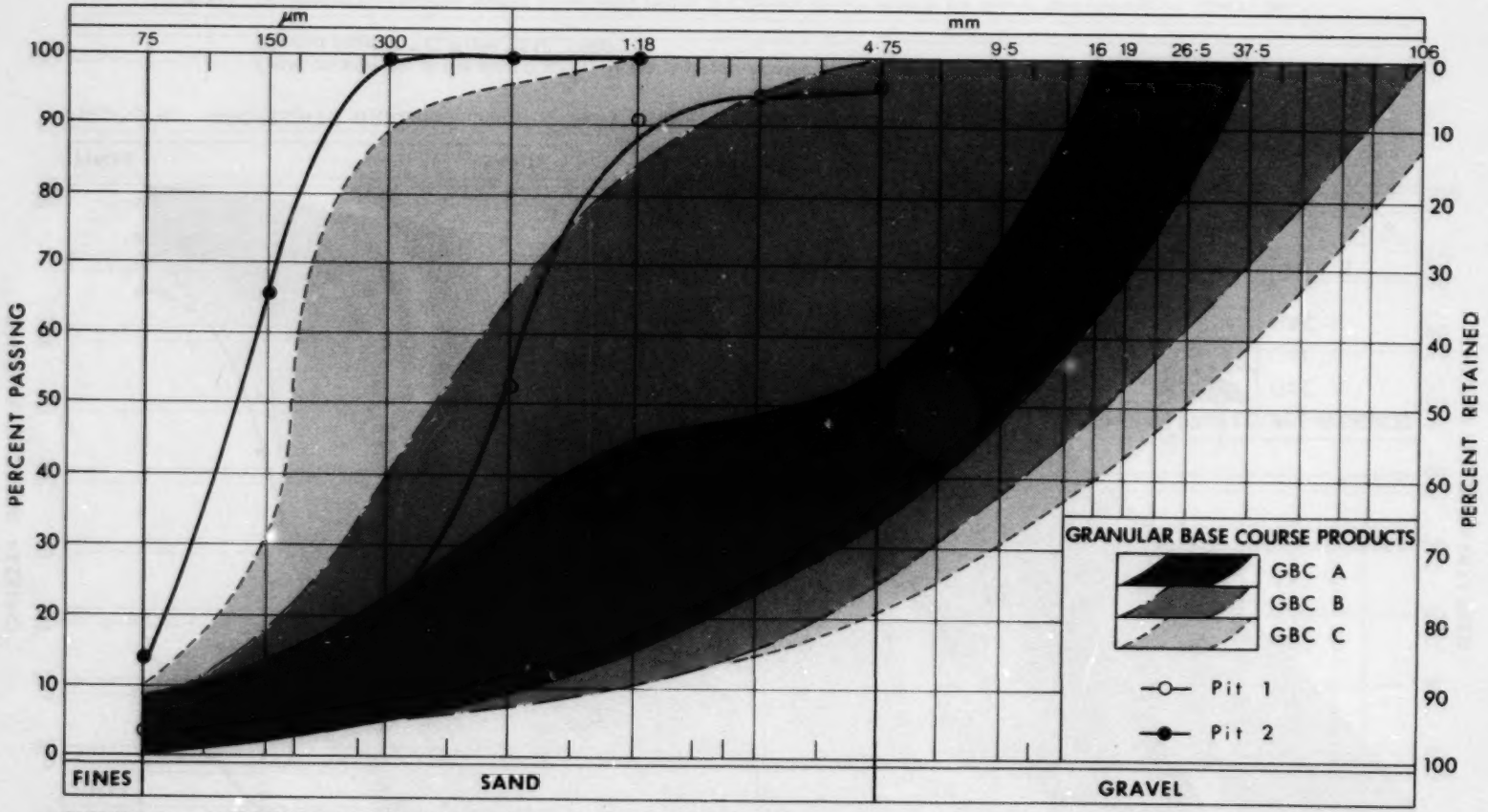


FIGURE 5: AGGREGATE GRADING CURVES, LOWTHER TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

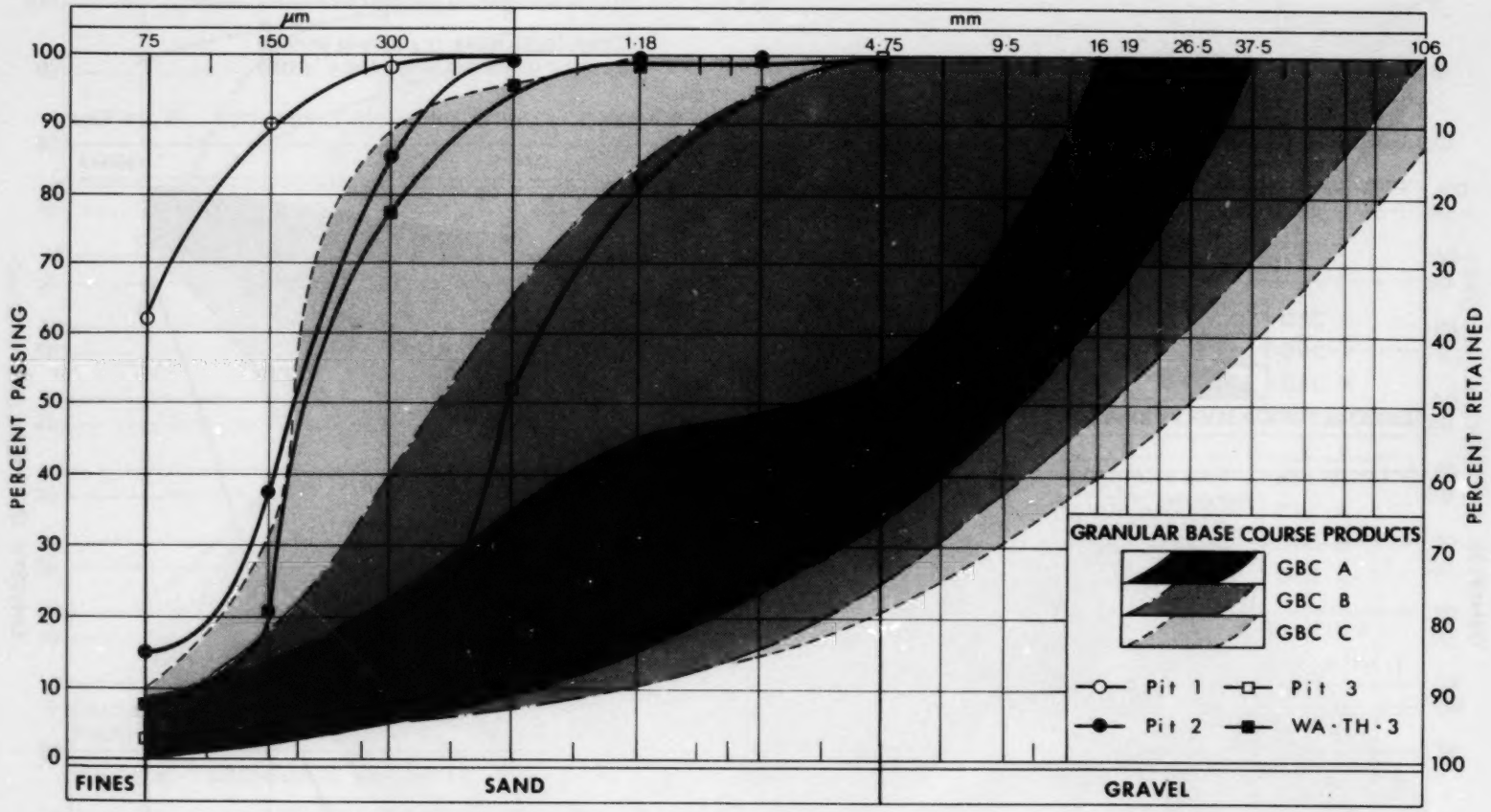


FIGURE 6: AGGREGATE GRADING CURVES, WAY TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

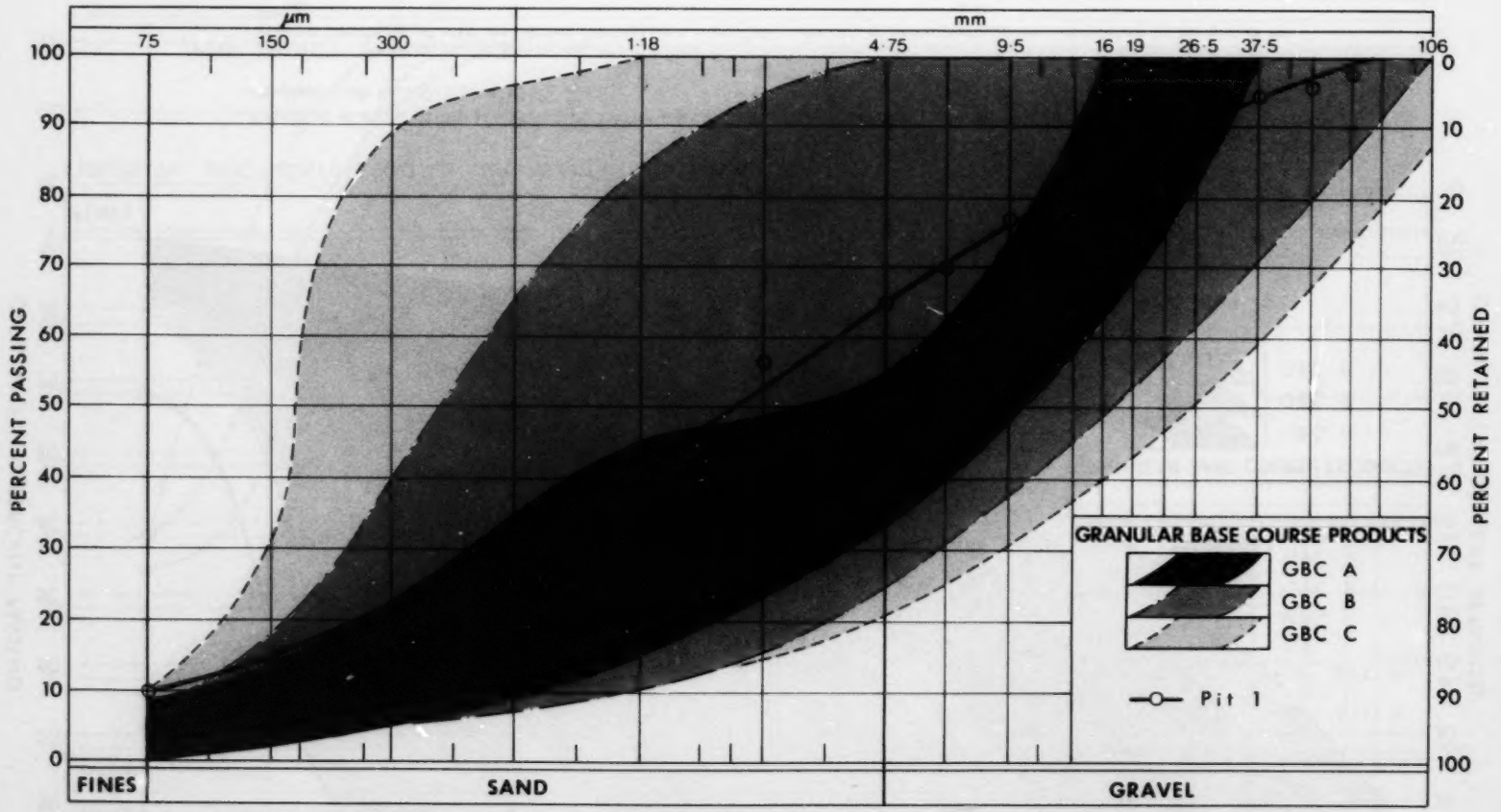


FIGURE 7a: AGGREGATE GRADING CURVES, DEVITT TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

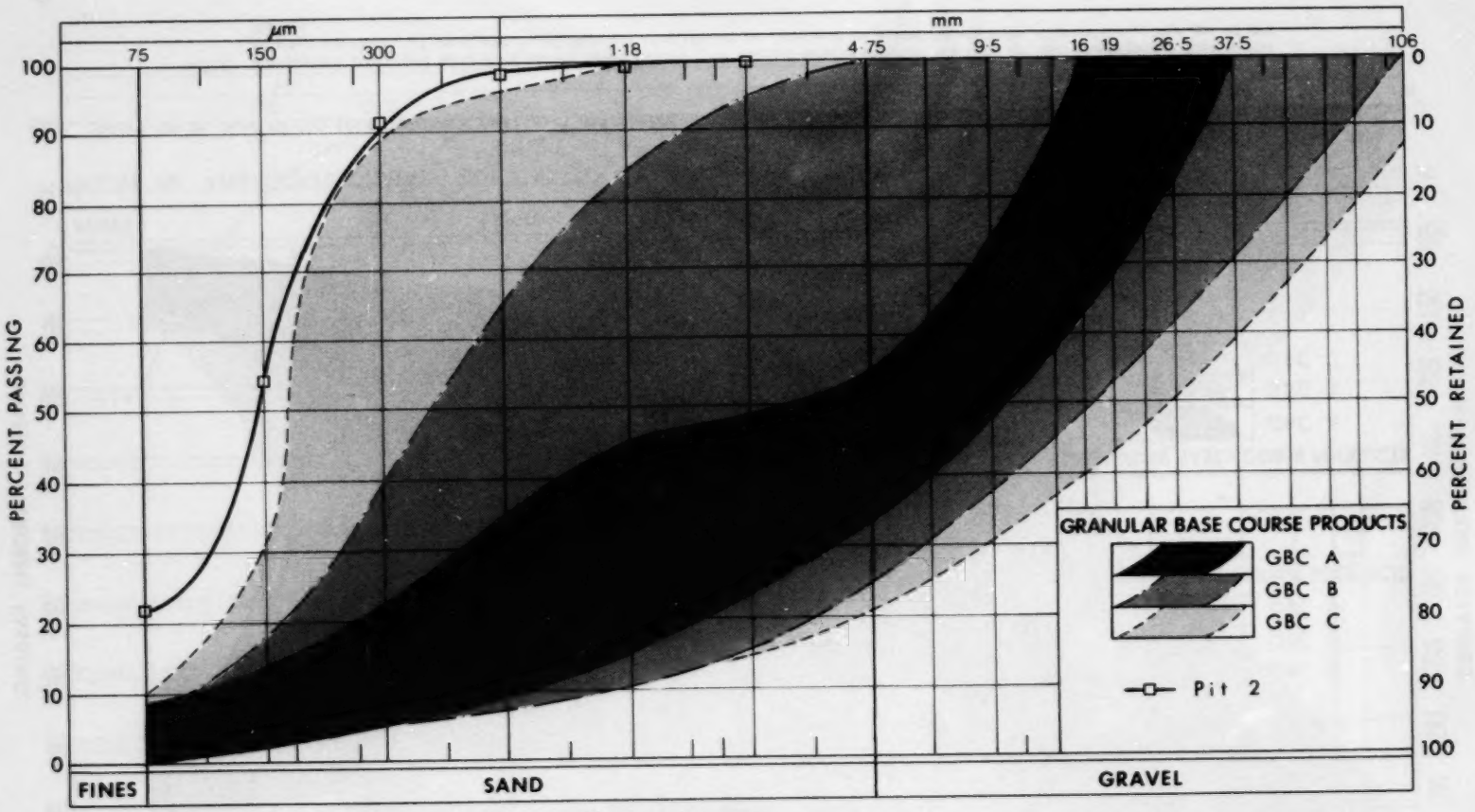


FIGURE 7b: AGGREGATE GRADING CURVES, DEVITT TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

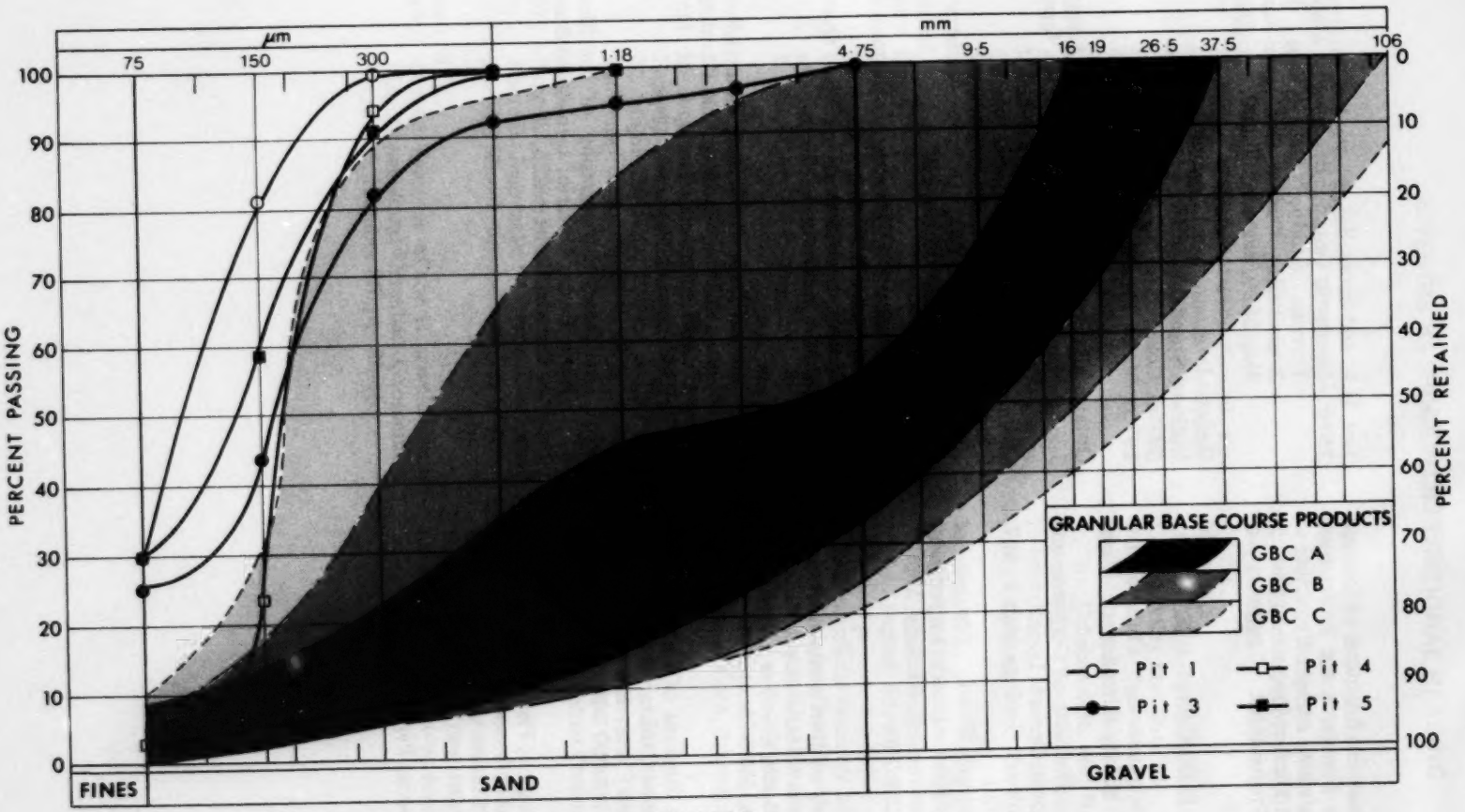


FIGURE 8: AGGREGATE GRADING CURVES, EILBER TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

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APPENDIX B - GLOSSARY

ABRASION RESISTANCE

Tests such as the Los Angeles Abrasion Test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

ABSORPTION CAPACITY

Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

AGGREGATE

Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

ALKALI-AGGREGATE REACTION

A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

BLENDING

Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

CLAST

An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering of a larger rock mass. Synonyms include particle and fragment.

CRUSHABLE AGGREGATE

Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

DELETERIOUS LITHOLOGY

A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone, and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions. Similarly, highly weathered, very porous and friable rock can restrict the quality of the aggregate.

DOLOSTONE

A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

DRIFT

A general term for all unconsolidated rock debris transported from one place and deposited in another; distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

DRUMLIN

A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were deposited beneath an advancing ice sheet, and were shaped by its flow.

EOLIAN

Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

FINES

A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

GNEISS

A coarse-textured metamorphic rock with the minerals arranged in parallel streaks or bands, but lacking schistosity. Gneiss is relatively rich in feldspar. Other common minerals found in this rock include quartz, mica, amphibole and garnet.

GRADATION

The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulders	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

GRANITE

Is a coarse-grained light coloured rock that ordinarily has an even texture and is composed of quartz, and feldspar with either mica, hornblende or both.

GRANULAR BASE COURSE

Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability, and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

HOT-LAID (OR ASPHALTIC) AGGREGATE

Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3, and 4), or as binder course (H.L. 2, 6, and 8) used to bind the surface course to the underlying granular base course.

LITHOLOGY

The description of rocks on the basis of such characteristics as color, structure, mineralogic composition, and grain size. Generally, the description of the physical character of a rock.

MAGNESIUM SULPHATE SOUNDNESS TEST

This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible will usually break down and give high losses in this test.

MELTWATER CHANNEL

A drainage way, usually terraced, produced by water flowing away from a melting glacier margin.

PETROGRAPHIC EXAMINATION

An aggregate quality test based on known field performance of various rock types. The test result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of aggregate.

PLEISTOCENE

An epoch of the recent geological past including the time from approximately 1.8 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

POSSIBLE RESOURCE

Estimates of mineral aggregate material based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

PRECAMBRIAN

The earliest geologic period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

SHALE

A fine-grained, sedimentary rock formed by the consolidation of clay, silt, or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone, and mudstone.

SOUNDNESS

The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

TILL

Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

WISCONSINAN

Pertaining to the last glacial stage of the Pleistocene Epoch in North America. It began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

APPENDIX C - GEOLOGY OF SAND AND GRAVEL DEPOSITS

The type, distribution, and extent of sand and gravel deposits in Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and they can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

ICE-CONTACT TERRACES (ICT)

These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous due to extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive due to the variability of the deposits both in terms of quality and grain size distribution.

KAMES (K)

Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the presence of excess fines (silt- and clay-sized particles).

ESKERS (E)

Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

UNDIFFERENTIATED ICE-CONTACT STRATIFIED DRIFT (IC)

This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits due to their lack of continuity and

grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

OUTWASH (OW)

Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the glacier. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

ALLUVIUM (AL)

Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and it has generally low value due to the presence of excess silt- and clay-sized material. There are no large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

GLACIOLACUSTRINE BEACH DEPOSITS (LB)

These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the underlying material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

GLACIOLACUSTRINE DELTAS (LD)

These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

GLACIOLACUSTRINE PLAIN (LP)

The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources due to their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

END MORAINES (EM)

These are belts of glacial drift deposited at, and parallel to, glacier margins. They commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

WINDBLOWN FORMS (WD)

Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments are almost

invariably composed of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

APPENDIX D - GEOLOGY OF BEDROCK DEPOSITS
(After Bennett et al. 1967a)

ROCK TYPE A - FELSIC INTRUSIVE ROCKS

These rocks display a wide range in composition and texture. They range from granite to quartz monzonite to granodiorite, massive to foliated with schlieren or fragments of gneissic material. Graphic granite is very common in the area.

The felsic intrusive rocks occur as batholithic intrusions and related satellite stocks, as lit-par-lit injection layers in the gneiss complex, and as dikes and stringers in the gneisses, metasediments, and metavolcanics.

ROCK TYPE B - MIGMATITE-METASEDIMENTARY-METAVOLCANIC COMPLEX

These rocks exhibit a wide range of composition and metamorphic structure. Pre-existing metamorphosed rocks were deformed and recrystallized, forming biotite and hornblende-quartz-feldspar-gneiss and granitic gneisses.

ROCK TYPE C - METASEDIMENTARY ROCKS

The predominant rock type is a fine-grained, massive to finely bedded, light to dark grey greywacke with greater than 80 percent quartz and feldspar. The remaining mineralization is made up of biotite, chlorite and sericite. Found with this rock type are fine-grained argillitic rocks, quartz layers, amphiboles and sandstone.

ROCK TYPE D - DIABASE DIKES

These rocks are fine to coarse grained and gabbroic to diabasic textured.